C & EE 141

Simple Shear Connections

Simple Shear Connections

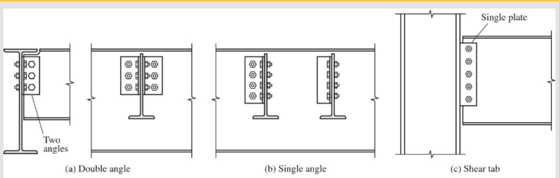
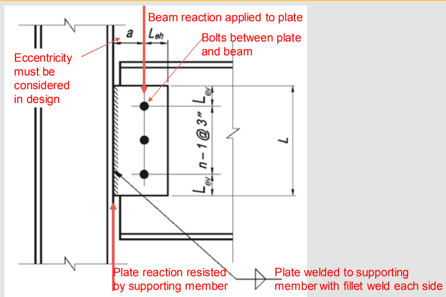


Figure 11.1 part 1

Simple Shear Connections

- Used to support simply supported beams at end connection
  - No moment resistance required
  - Must allow some rotation to occur at beam end (per pinned end assumption)
- Several types standardized with design tables in Part 10 of AISC SCM
- Single-Plate Connection is most common in local construction

Single-Plate Connections



Single-Plate Connections

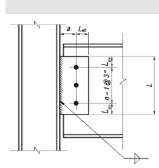
- See Page 10-102 of AISC SCM for design procedure
  - Ensures that limit state is flexural yielding of connecting plate (not bolt shear)
- Conventional Configuration: may use Table 10-10
  - 2 to 12 bolts located in a single line
  - Distance from bolt line to supports ≤ 3 1/2"
  - Standard or short-slotted holes
  - Vertical edge distance per Table J3.4.
  - Horizontal edge distance ≥ 2d
  - Plate or beam web thickness limited per Table 10-9
- Weld at each side of plate to supporting member is (5/8)t_{plate}

Single-Plate Connections

3/4-in.-diameter bolts — **Table 10-10a (continued) Single-Plate Connections** — Bolt, Weld and Single-Plate Available Strengths, kips — Plate F_y = 36 ksi

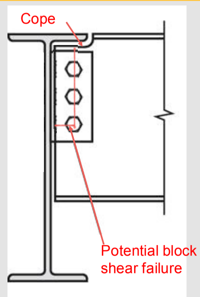
n	Bolt Group	Thread Cond.	Hole Type	Plate Thickness, in. 1/4 ASD	1/4 LRFD	5/16 ASD	5/16 LRFD	3/8 ASD	3/8 LRFD	7/16 ASD	7/16 LRFD	1/2 ASD	1/2 LRFD	9/16 ASD	9/16 LRFD
4 (L = 11 1/2)	Group A	N	STD	34.8	52.2	41.5	62.5	41.5	62.5	41.5	62.5	—	—	—	—
			SSLT	34.7	52.0	41.5	62.5	41.5	62.5	41.5	62.5	41.5	62.5	41.5	62.5
		X	STD	34.8	52.2	43.5	65.3	52.2	78.3	52.4	78.5	—	—	—	—
			SSLT	34.7	52.0	43.4	65.1	52.0	78.1	52.4	78.5	52.4	78.5	52.4	78.5
	Group B	N	STD	34.8	52.2	43.5	65.3	52.2	78.3	52.4	78.5	—	—	—	—
			SSLT	34.7	52.0	43.4	65.1	52.0	78.1	52.4	78.5	52.4	78.5	52.4	78.5
		X	STD	34.8	52.2	43.5	65.3	52.2	78.3	60.9	91.4	—	—	—	—
			SSLT	34.7	52.0	43.4	65.1	52.0	78.1	60.7	91.1	64.9	97.0	64.9	97.0
Weld Size				3/16		1/4		1/4		5/16		5/16		3/8	

STD = Standard holes
SSLT = Short-slotted holes transverse to direction of load
— Indicates that the plate thickness is greater than the maximum given in Table 10-9.
N = Threads included
X = Threads excluded



Beam Coping

- Beam-to-Girder connections may require "coping" of the top flange to accommodate connections within parameters of Conventional Configuration
- Must check block shear on connected beam web when top flange is coped



Example

C & EE 141

Welded Connections

Welded Connections

- **EXTREMELY IMPORTANT TOPIC!!!!**
  - Inadequate connection design is the cause of many structural failures
- Definition
  - A process by which metallic parts are connected by heating their surfaces to a plastic or fluid state and allowing the parts to flow together and join (with or without the addition of other molten metal)





Pros & Cons

- Pros
  - Savings in steel material
  - Broader application than bolting
  - Aesthetically more pleasing than bolts
  - Easy to correct errors in the field
- Cons
  - Need welding equipment
  - Fire safety issues
  - Toxicity issues
  - Time consuming compared to bolting in the field
  - Preheat requirements
  - Testing requirements to ensure good weld

Welding Processes

- SMAW – Shielded Metal Arc Welding
  - “Stick” welding (hand held electrode is the “stick”)
  - General purpose; used for most building construction
- FCAW – Flux-Cored Arc Welding
  - Flux filled steel tube electrode fed from a reel
  - High production/automation
- SAW – Submerged Arc Welding
  - Electrode is fed from a reel (usually automated)
  - Suitable for long straight and circumferential welds
- GMAW – Gas Metal Arc Welding
  - Arc is shielded by gas cloud (typ. oxygen or argon)
  - High production/automation

Welding a Column Splice

http://www.youtube.com/watch?v=u54onu0R5TQ

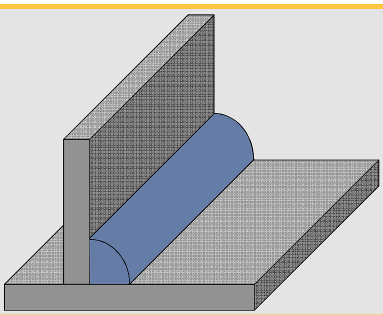


Types of Welds

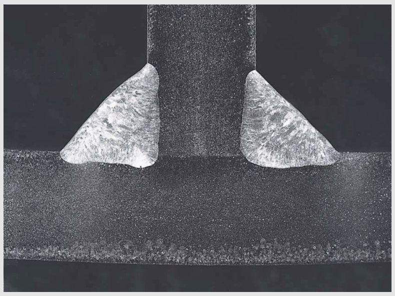
- Fillet weld
- Groove weld
  - Partial penetration groove weld
  - Complete penetration groove weld
- Plug & slot welds
- Flare

Fillet Weld

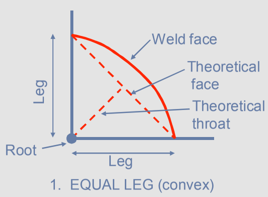
- Most common, simplest weld
- Doesn't require preparation of members to be joined
- Generally least expensive

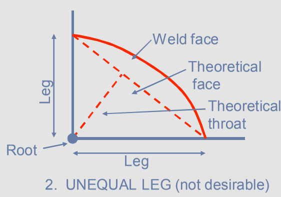


Fillet Weld



Fillet Weld Throat

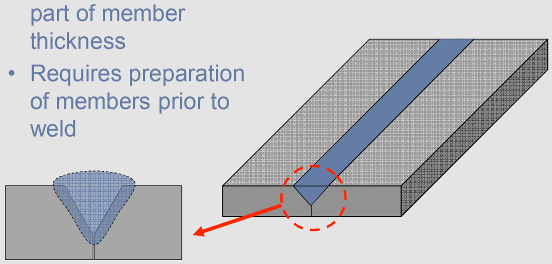




- Theoretical throat = Cos(45°) x Leg
- Theoretical throat = 0.707 x Leg
- Theoretical throat also called "effective throat"

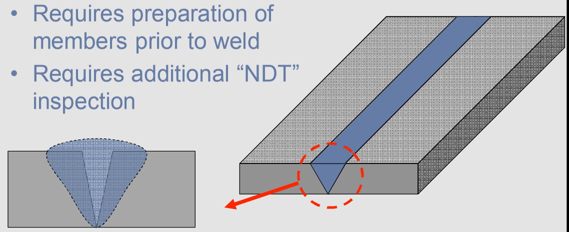
Partial Penetration Groove Weld

- Weld extends through part of member thickness
- Requires preparation of members prior to weld



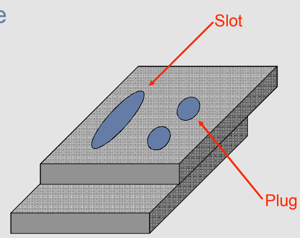
Complete Penetration Groove Weld

- Weld extends through full member thickness
- Requires preparation of members prior to weld
- Requires additional “NDT” inspection



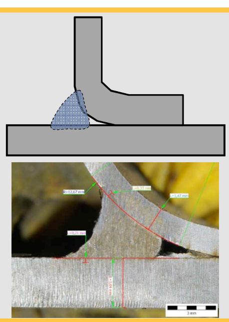
Plug & Slot Welds

- Hole or slot cut in one of members to be joined
- Hole filled partially or fully with weld metal
- Used to stitch parts together
- Not a reliable choice for transferring shear

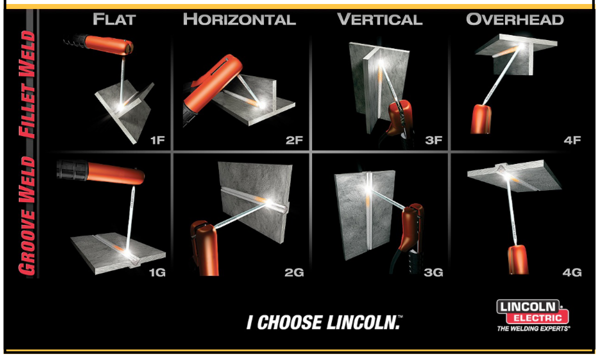


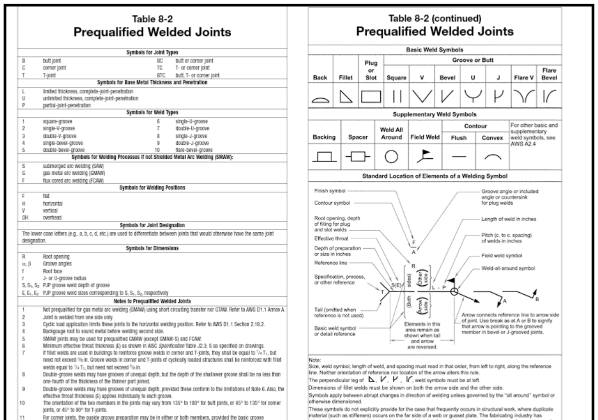
Flare Groove Weld

- Very common weld
- Proper designation for welding the edge of a curved member to a flat one (often mistakenly called-out as a fillet weld)
- Doesn’t require preparation of members to be joined



Welding Positions





Pg 8-34 & 35

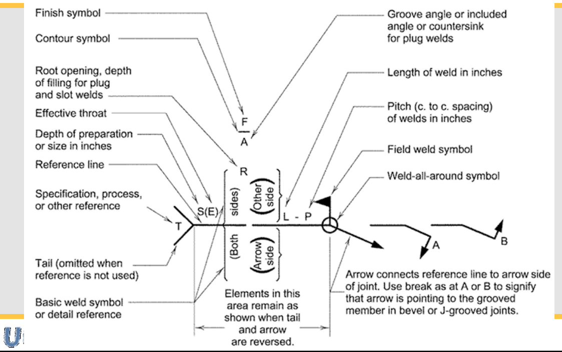
Basic Weld Symbols

Table 8-2 (continued)
Prequalified Welded Joints

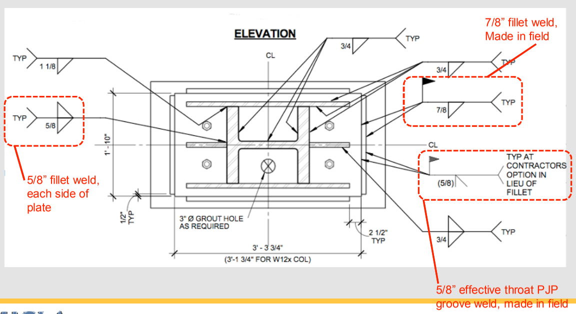
Basic Weld Symbols										
			Groove or Butt							
Back	Fillet	Plug or Slot	Square	V	Bevel	U	J	Flare V	Flare Bevel

Supplementary Weld Symbols						
				Contour		
Backing	Spacer	Weld All Around	Field Weld	Flush	Convex	For other basic and supplementary weld symbols, see AWS A2.4

Basic Weld Symbols



Example Weld Callouts



Filler Metal Requirements

- Weld filler metal typically designated E60XX, E70XX, etc.
- Strength of filler metal indicated by first two numbers (ksi)
- Filler metal strength requirements vary according to base metal. Given by AISC specification.

User Note: The following User Note Table summarizes the AWS D1.1/D1.1M provisions for matching filler metals. Other restrictions exist. For a complete list of base metals and prequalified matching filler metals see AWS D1.1/D1.1M, Table 3.1.

Base Metal		Matching Filler Metal
A36 ≤ 3/4 in. thick		60 & 70 ksi filler metal
A36 > 3/4 in. A588* A1011	A572 (Gr. 50 & 55) A913 (Gr. 50) A992 A1018	SMAW: E7015, E7016, E7018, E7028 Other processes: 70 ksi filler metal
A913	(Gr. 60 & 65)	80 ksi filler metal

*For corrosion resistance and color similar to the base metal, see AWS D1.1/D1.1M, subclause 3.7.3.

Notes:
Filler metals shall meet the requirements of AWS A5.1, A5.5, A5.17, A5.18, A5.20, A5.23, A5.28 or A5.29.
In joints with base metals of different strengths, use either a filler metal that matches the higher strength base metal or a filler metal that matches the lower strength and produces a low hydrogen deposit.

Design Strength of Welds

Fillet Welds

TABLE J2.5 (continued)
Available Strength of Welded Joints, ksi (MPa)

Load Type and Direction Relative to Weld Axis	Pertinent Metal	ϕ and Ω	Nominal Stress (F_{nBM} or F_{nw}) ksi (MPa)	Effective Area (A_{BM} or A_{we}) in.^{2} (mm^2)	Required Filler Metal Strength Level [a][b]
FILLET WELDS INCLUDING FILLETS IN HOLES AND SLOTS AND SKEWED T-JOINTS					
Shear	Base	Governed by J4			Filler metal with a strength level equal to or less than matching filler metal is permitted.
	Weld	$\phi = 0.75$ $\Omega = 2.00$	$0.60F_{EXX}$ [d]	See J2.2a	
Tension or compression Parallel to weld axis	Tension or compression in parts joined parallel to a weld need not be considered in design of welds joining the parts.				
PLUG AND SLOT WELDS					
Shear Parallel to faying surfaces on the effective area.	Base	Governed by J4			Filler metal with a strength level equal to or less than matching filler metal is permitted.
	Weld	$\phi = 0.75$ $\Omega = 2.00$	$0.60F_{EXX}$	See J2.3a	

[a] For matching weld metal see AWS D1.1/D1.1M, Section 3.3.
[b] Filler metal with a strength level one strength level greater than matching is permitted.
[c] Filler metals with a strength level less than matching may be used for groove welds between the webs and flanges of built-up sections transferring shear loads, or in applications where high restraint is a concern. In these applications, the weld joint shall be detailed and the weld shall be designed using the thickness of the material as the effective throat, where $\phi = 0.80$, $\Omega = 1.88$ and $0.60F_{EXX}$ is the nominal strength.
[d] Alternatively, the provisions of Section J2.4(a) are permitted provided the deformation compatibility of the various weld elements is considered. Sections J2.4(b) and (c) are special applications of Section J2.4(a) that provide for deformation compatibility.

Strength of Fillet Welds

$$F_w = 0.60 F_{EXX} A_{ns}$$

- F_{EXX} = strength of the weld filler metal
- A_{ns} = net area (effective throat x weld length)
- Φ = 0.75

Strength of Fillet Welds

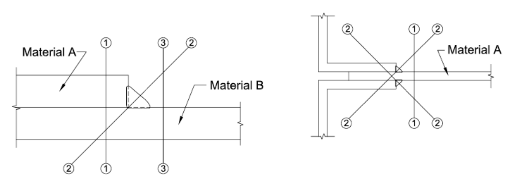


Fig. C-J2.10. Shear planes for fillet welds loaded in longitudinal shear.

Plane ①-① for material *(A)*
Plane ②-② for weld metal
Plane ③-③ for material *(B)*

Other Fillet Weld Considerations

- Minimum size per Table J2.4
  - Must have enough weld heat to prevent rapid cooling (based on size of plates being joined)

TABLE J2.4
Minimum Size of Fillet Welds

Material Thickness of Thinner Part Joined, in. (mm)	Minimum Size of Fillet Weld,[a] in. (mm)
To 1/4 (6) inclusive	1/8 (3)
Over 1/4 (6) to 1/2 (13)	3/16 (5)
Over 1/2 (13) to 3/4 (19)	1/4 (6)
Over 3/4 (19)	5/16 (8)

[a] Leg dimension of fillet welds. Single pass welds must be used.
Note: See Section J2.2b for maximum size of fillet welds.

Other Fillet Weld Considerations

- Maximum size
  - For edges less than ¼”, not greater than the thickness of material
  - For edges ¼” or more, use thickness of material minus $^1/_{16}$”
- Minimum effective length
  - 4 x nominal size
- Maximum effective length and reductions
  - ≤ 100 x leg » no strength reduction
  - > 100 x leg » strength reduction = $\beta = 1.2 - 0.002(L/w) \le 1.0$
  - > 300 x leg » strength reduction = $\beta = 0.6$

Other Fillet Weld Considerations

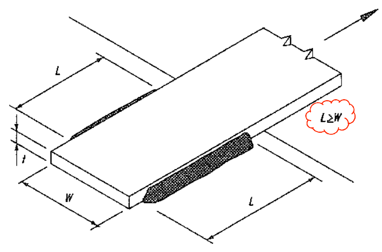


Fig. C-J2.2. Longitudinal fillet welds.

Weld Strength

Complete Penetration Joint Welds

TABLE J2.5 Available Strength of Welded Joints, ksi (MPa)

Load Type and Direction Relative to Weld Axis	Pertinent Metal	ϕ and Ω	Nominal Stress (F_{nBM} or F_{nw}) ksi (MPa)	Effective Area (A_{BM} or A_{we}) in.^{2} (mm^2)	Required Filler Metal Strength Level [a][b]
COMPLETE-JOINT-PENETRATION GROOVE WELDS					
Tension Normal to weld axis	Strength of the joint is controlled by the base metal				Matching filler metal shall be used. For T- and corner joints with backing left in place, notch tough filler metal is required. See Section J2.6.
Compression Normal to weld axis	Strength of the joint is controlled by the base metal				Filler metal with a strength level equal to or one strength level less than matching filler metal is permitted.
Tension or compression Parallel to weld axis	Tension or compression in parts joined parallel to a weld need not be considered in design of welds joining the parts.				Filler metal with a strength level equal to or less than matching filler metal is permitted.
Shear	Strength of the joint is controlled by the base metal				Matching filler metal shall be used.[c]

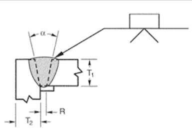
Strength of CJP Welds

- The strength is that of the Base Metal
- The purpose of a CJP is to develop the FULL strength of the Base Metal
- Most expensive type of weld
  - Process highly controlled
  - Increased Testing and Inspection
  - More preparation and clean-up
- Use only when absolutely necessary

CJP

Table 8-2 (continued)
Prequalified Welded Joints
Complete-Joint-Penetration Groove Welds

Single-V-groove weld (2)
Corner joint (C)



Tolerances	
As Detailed (see 3.13.1)	As Fit-Up (see 3.13.1)
R = +1/16, −0	+1/4, −1/16
α = +10°, −0°	+10°, −5°

Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)		Groove Preparation		Allowed Welding Positions	Gas Shielding for FCAW	Notes
		T_1	T_2	Root Opening	Groove Angle			
SMAW	C-U2a	U	U	R = 1/4	α = 45°	All	—	5, 10
				R = 3/8	α = 30°	F, V, OH	—	5, 10
				R = 1/2	α = 20°	F, V, OH	—	5, 10
GMAW FCAW	C-U2a-GF	U	U	R = 3/16	α = 30°	F, V, OH	Required	1
				R = 3/8	α = 30°	F, V, OH	Not req.	1, 10
				R = 1/4	α = 45°	F, V, OH	Not req.	1, 10
SAW	C-L2a-S	2 max	U	R = 1/4	α = 30°	F	—	10
SAW	C-U2-S	U	U	R = 5/8	α = 20°	F	—	10

Weld Strength

Partial Joint Penetration Welds

TABLE J2.5
Available Strength of Welded Joints, ksi (MPa)

Load Type and Direction Relative to Weld Axis	Pertinent Metal	ϕ and Ω	Nominal Stress (F_{BM} or F_w) ksi (MPa)	Effective Area (A_{BM} or A_{we}) in.² (mm²)	Required Filler Metal Strength Level
PARTIAL-JOINT-PENETRATION GROOVE WELDS INCLUDING FLARE V-GROOVE AND FLARE BEVEL GROOVE WELDS					
Tension Normal to weld axis	Base	$\phi = 0.75$ $\Omega = 2.00$	F_u	See J4	Filler metal with a strength level equal to or less than matching filler metal is permitted.
	Weld	$\phi = 0.80$ $\Omega = 1.88$	$0.60F_{EXX}$	See J2.1a	
Compression Column to base plate and column splices designed per Section J1.4(1)	Compressive stress need not be considered in design of welds joining the parts.				
Compression Connections of members designed to bear other than columns as described in Section J1.4(2)	Base	$\phi = 0.90$ $\Omega = 1.67$	F_y	See J4	
	Weld	$\phi = 0.80$ $\Omega = 1.88$	$0.60F_{EXX}$	See J2.1a	
Compression Connections not finished-to-bear	Base	$\phi = 0.90$ $\Omega = 1.67$	F_y	See J4	
	Weld	$\phi = 0.80$ $\Omega = 1.88$	$0.90F_{EXX}$	See J2.1a	
Tension or compression Parallel to weld axis	Tension or compression in parts joined parallel to a weld need not be considered in design of welds joining the parts.				
Shear	Base	Governed by J4			
	Weld	$\phi = 0.75$ $\Omega = 2.00$	$0.60F_{EXX}$	See J2.1a	

Strength of PJP Welds

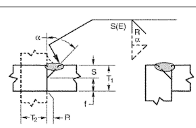
Weld Metal: $$R_n = 0.60\,F_{EXX}\,A_{ns}$$

Base Metal: $$R_n = F_{BM}\,A_{BM}$$

- F_{BM} = Strength of the Base Metal (F_u)
- A_{BM} = cross-sectional area of Base Metal
- F_{EXX} = strength of the weld metal
- A_{ns} = net area (effective throat x weld length)
- Φ = 0.80 for weld
- Φ = 0.75 for base metal

Table 8-2 (continued) **PJP**
Prequalified Welded Joints
Partial-Joint-Penetration Groove Welds

Single-bevel-groove weld (4)
Butt joint (B)
T-joint (T)
Corner joint (C)



Welding Process	Joint Designation	Base Metal Thickness (U = unlimited) T_1	T_2	Groove Preparation: Root Opening Root Face Groove Angle	Tolerances: As Detailed (see 3.12.3)	Tolerances: As Fit-Up (see 3.12.3)	Allowed Welding Positions	Total Weld Size (E)	Notes
SMAW	BTC-P4	U	U	R = 0 f = 1/8 min α = 45°	+1/16, –0 +U, –0 +10°, –0°	+1/8, –1/16 ±1/16 + 10°, –5°	All	S–1/8	2, 5, 6, 7, 10, 11
GMAW FCAW	BTC-P4-GF	1/4 min	U	R = 0 f = 1/8 min α = 45°	+1/16, –0 +U, –0 +10°, –0°	+1/8, –1/16 ±1/16 + 10°, –5°	F, H V, OH	S S–1/8	1, 2, 6, 7, 10, 11
SAW	TC-P4-S	7/16 min	U	R = 0 f = 1/4 min α = 60°	±0 +U, –0 +10°, –0°	+1/16, –0 ±1/16 + 10°, –5°	F	S	2, 6, 7, 10, 11

Effective Throat of PJP Welds

TABLE J2.1
Effective Throat of Partial-Joint-Penetration Groove Welds

Welding Process	Welding Position F (flat), H (horizontal), V (vertical), OH (overhead)	Groove Type (AWS D1.1/D1.1M, Figure 3.3)	Effective Throat
Shielded metal arc (SMAW)	All	J or U groove	depth of groove
Gas metal arc (GMAW) Flux cored arc (FCAW)		60° V	
Submerged arc (SAW)	F	J or U groove 60° bevel or V	
Gas metal arc (GMAW) Flux cored arc (FCAW)	F, H	45° bevel	depth of groove
Shielded metal arc (SMAW)	All	45° bevel	depth of groove minus 1/8 in. (3 mm)
Gas metal arc (GMAW) Flux cored arc (FCAW)	V, OH		

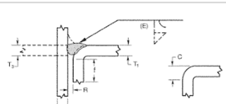
Weld Strength

Flare Groove Welds

FLARE

Table 8-2 (continued)
Prequalified Welded Joints
Flare-Bevel Groove Welds

Flare-bevel-groove weld (10)
Butt joint (B)
T-joint (T)
Corner joint (C)



Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)			Groove Preparation			Allowed Welding Positions	Total Weld Size (E)	Notes
						Tolerances				
		T_1	T_2	T_3	Root Opening Root Face Bend Radius*	As Detailed (see 3.12.3)	As Fit-Up (see 3.12.3)			
SMAW FCAW-S	BTC-P10	3/16 min	U	T_1 min	R = 0 f = 3/16 min $C = \frac{3T_1}{2}$ min	+1/16, −0 +U, −0 +U, −0	+1/8, −1/16 +U, −1/16 +U, −0	All	$\frac{5T_1}{8}$	5, 7, 10, 12
GMAW FCAW-G	BTC-P10-GF	3/16 min	U	T_1 min	R = 0 f = 3/16 min $C = \frac{3T_1}{2}$ min	+1/16, −0 +U, −0 +U, −0	+1/8, −1/16 +U, −1/16 +U, −0	All	$\frac{5T_1}{4}$	1, 7, 10, 12
SAW	B-P10-S	1/2 min	N/A	1/2 min	R = 0 f = 1/2 min $C = \frac{3T_1}{2}$ min	±0 +U, −0 +U, −0	+1/16, −0° +U, −1/16 +U, −0	F	$\frac{5T_1}{8}$	7, 10, 12

Effective Weld Size of Flare Groove Welds

TABLE J2.2
Effective Weld Throats of Flare Groove Welds

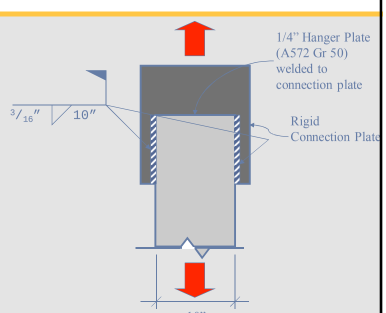
Welding Process	Flare Bevel Groove[a]	Flare V-Groove
GMAW and FCAW-G	$\frac{5}{8}R$	$\frac{3}{4}R$
SMAW and FCAW-S	$\frac{5}{16}R$	$\frac{5}{8}R$
SAW	$\frac{5}{16}R$	$\frac{1}{2}R$

[a] For flare bevel groove with $R < 3/8$ in. (10 mm), use only reinforcing fillet weld on filled flush joint.
General note: R = radius of joint surface (can be assumed to be $2t$ for HSS), in. (mm)

Questions?

Example Problem #1

- Calculate the capacity of the welded connection.
- Fexx = 70 ksi



Connection Detail

Example Problem #1

A572 Grade 50 Steel
F_y = 50 ksi; F_u = 65 ksi

Filler Weld Capacity
Fexx = 70 ksi

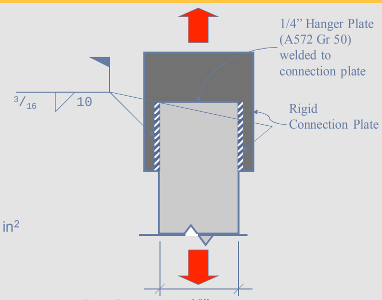
Strength of Connection:
Yielding of plate:

A_g = ¼" · 10" = 2.5 in^2

$\Phi P_n = \Phi F_y \cdot A_g$
= 0.9 · 50 ksi · 2.5 in^2
= 113 *kips*

Capacity of Weld:

$\Phi P_n = \Phi 0.6 F_{exx} t_e L$
= (0.75)(0.6)(70ksi)(0.707x3/16")(20")
= **83.5 *kips* *Governs***



Connection Detail